SURFACE INSPECTION ON MHI-01~09 CAVITIES

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Abstract

Nine 1.3 GHz 9-cell superconducting cavities (MHI-01 ~ 09) were fabricated from 2005 to 2009 at KEK-STF for International Linear Collider (ILC) project. The vertical test with temperature mapping and X-ray mapping, and the optical inspection by Kyoto camera system of nine 9-cell cavities were carried out from 2005 to 2010 for STF Phase 1.0 and S1-Global project at KEK. Two new cavities (MHI-10 and MHI-11) is under fabricating for S0 program for ILC.

The cavities classify into four series. The 1st series is MHI-01 ~ 04 (fabricated at 2005). They were made the centrifugal barrel polishing (CBP) at initial surface treatment. The 2nd series is MHI-05 and 06 (fabricated 2008). The 3rd series is MHI-07 ~ 09 (fabricated at 2009). The 4th series is MHI-10 ~ 11 (fablicated at 2009). The surface treatment to remove the material of 2nd and 3rd seires cavitiy was made only Electro Polishing (EP) (without CBP), because of the quarity of EBW seams of equator and iris was improved by the feedback of the optical inspection by Kyoto camera system.

A good correlation has been so far observed between the hot spots localized by thermometry measurements in the vertical test and the positions of surface defects found by this system. The result of the optical inspection will be reported in this paper.

INTRODUCTION

The optical inspection system with high-resolution camera is developed to search defects and measure the shape of them for better yield of accelerating gradient of 1.3 GHz 9-cell superconducting cavities [1].

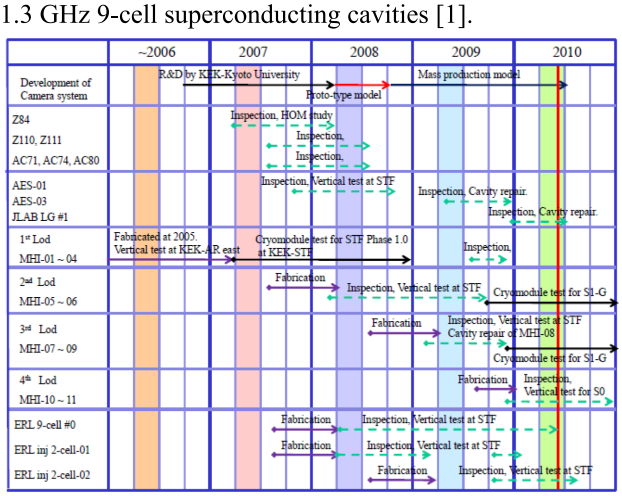


Figure 1: History of the inspection system and fabrication of the cavity.

The purpose of optical inspection is to search a correlation between a heating location detected by Temperature mapping and irregularity of the inner surface inspected by Kyoto camera system, and accelerating field level measured by Vertical Test when a heating has started. The goal of this study is to have reference of size of the geometrical defect to estimate a cavity performance by the optical inspection. It is important for industrialization of cavity fabrication to make a suitable production control (Surface inspection of material, EBW inspection and the inspection of surface treatment etc.). So far, the inspection systems are adopted at labs around the world.

Eleven MHI cavities were made the several surface treatments to achieve the good cavity performance. Figure 1 shows the history of development of the Kyoto camera system, and the fabrication of the MHI cavities. The proto-type camera system was completed at Mar 2008. The full-scale optical inspection study also was started from Mar 2008.

SURFACE INSPECTION OF MHI CAVITIES

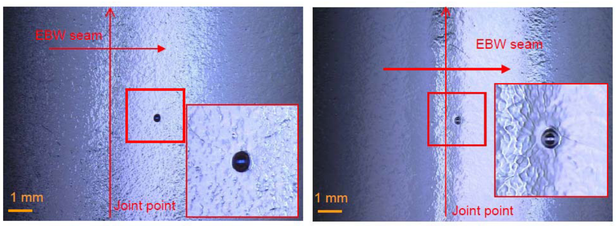
Eleven 1.3 GHz 9-cell superconducting cavities (MHI-01 ~ 11) were favricated by MHI from 2005 to 2010. The optical inspection with T-mapping result for Nine 9-cell cavities (MHI-01 ~ MHI-09) was done. The cavities had several suspicious defect at inside cavity. The surface conditon and the found defects after several treatment will be reported in this section.

Inspection of 1st series cavity (MHI-01~04)

The MHI-01 ~ 04 were fabricated at 2005. The optical inspection was not done at "as built", because of the 1st series cavity was fabricated before the Kyoto camera system was developed. The gradient of three cavities (MHI-01, MHI-03, MHI-04) was reached about 17 ~ 20 MV/m. The best performance of 1st series was MHI-02. It was reached 29 MV/m in pi-mode at vertical test [2].

The parameter of electron beam welding (EBW) for cell equators was not perfect in that time. To obtain the smooth surface and remove the defects around equators at inside cavity, the centrifugal barrel polishing (CBP) was made at initial surface treatment. The vertical tests for four cavities were carried out from Feb 2005 to Mar 2007 for STF phase 1.0. The T-mapping also was attached in these test, however, the number of thermo-sensor was small (four sensors per one cell (angle is 0, 90, 180, 270 deg. on the equator), total number is 36 sensors). Only rough quench location can be defected by combination of this old T-mapping and passband measurement.

The optical inspection after finished STF Phase 1.0 was done at Sep 2009. Surface condition and typical defect of 1st series cavity are shown in Figure 2. The surface condition looks like the satin finish surface due to CBP. The pit type defects were found around equators. Locations of these pits were (a) on the EBW seam and (b) on the boundary between EBW seam and heat affected zone. In the outside weld area around equators, there was no defect. All 1st series cavities had few pit type defects at the similar location shown by Figure 2. The defects existed around equator though the surface was grinded by CBP at initial treatment.



MHI-01 (2) #3-cell equator, t=231 deg. MHI-04 (1) #1-cell equator, t=087 deg.

Figure 2: Typical defects of 1st series cavities.

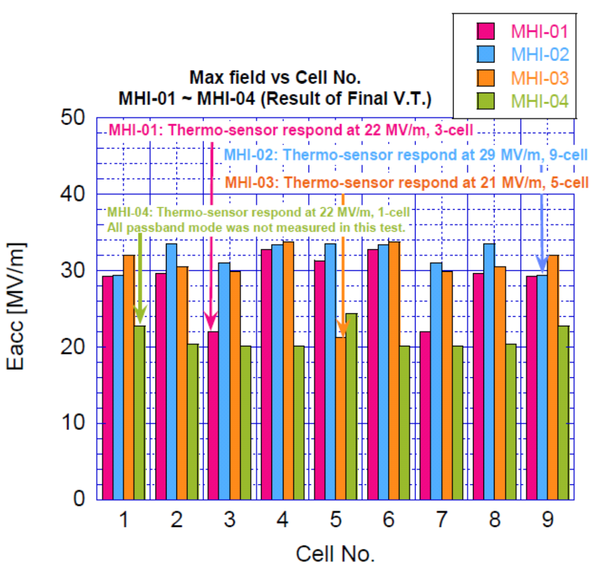


Figure 3: Summary of passband mode measurement in vertical test with old T-mapping.

Table 1 is the summary of the amount of removed material and number of the defect for 1st series cavities. Figure 3 shows the summary of the result of passband measurement at final vertical tests. The thermo-sensors responded at quench in pi-mode and passband measurement in all tests. In the MHI-01, MHI-03 and MHI-04, the geometrical defects found at equator of quenched cell, however, the number of thermo-sensor of old T-mapping was small. The position resolution is not enough. The vertical test with full-scale T-mapping system for 1st series cavity must make to check that "found defects are really reason of cause of quench".

Table 1: History of the surface, treatment and found defects after Phase 1.0

Cavity	History of Removed material [µm]	Number of Defects around equator [µm]
MHI-01	CBP (~ 100) Bulk EP (100) EP-2 (50), V.T. EP-2 (30), V.T. EP-2 (20), V.T. CBP (~100) Bulk EP (100) EP-2 (50), V.T. Total = 550 um	(1) #2-cell equator, t=051 deg. Pit ϕ 600, depth 65µm (2) #3-cell equator, t=231 deg. Pit ϕ 350, over range. (3) #9-cell equator, t=000 deg. Pit ϕ 350, depth 10µm. (4) #9-cell equator, t=079 deg. Pit ϕ 550, depth 25µm Thermo-sensor of #3-cell, t=270 deg was respond at quench.
MHI-02	CBP (~100) Bulk EP (100) EP-2 (50), V.T. EP-2 (30), V.T. EP-2 (30), V.T. CBP (~100) Bulk EP (100) EP-2 (50), V.T. Total = 560 um	(1) #9-cell equator, t=000 deg. Pit ϕ 450, depth 45µm Thermo-sensors of #9-cell, t=135, 180 deg were respond at quench.
MHI-03	CBP (~100) Bulk EP (100) EP-2 (50), V.T. CBP (~150) Bulk EP (100) EP-2 (50), V.T. Total = 550 um	(1) #5-cell equator, t=131 deg. Pit ϕ 300, depth ??? Need to make replica. Thermo-sensor of #5-cell, t=90 deg was respond at quench.
MHI-04	CBP (~100) Bulk EP (120) EP-2 (50), V.T. CBP (~100) Bulk EP (100) EP-2 (50), V.T. EP-2 (20), V.T. Total = 560 um	(1) #1-cell equator, t=087 deg. Pit ϕ 350, depth 30µm (2) #1-cell equator, t=187 deg. Pit ϕ 200, over range (3) #3-cell equator, t=022 deg. Pit ϕ 300, over range (4) #8-cell equator, t=180 deg. Pit. ϕ 250, over range Thermo-sensor of #1-cell, t=90 deg was respond at quench.

In the MHI-02, thermo-sensor responded at quench, however, the defect was not existed near responded thermo-sensor.

Inspection of 2nd series cavity (MHI-05 ~ 06)

2nd series cavity were fabricated at 2008. The surface treatment to remove material was EP only. The optical inspection of mock-up was done before welding all equators to check a good parameter of EBW. The optical inspection at "as built" was started from this series. The 2nd series cavity had both of the uniform area and the non-uniform area at around the EBW seam of the equators (see Figure 4). The non-uniform area of EBW seam has a possibility for a reason of the limitation to achieve a high accelerating gradient [3],[4],[5]. Possible reason of the non-uniform EBW seam is seemed as the material thickness error of the joint point of the equator. The two types suspicious spots were found at outside of weld area after Bulk EP. The diameter and depth of the pit type spots were 200 ~ 500 μm diameter and 10 ~ 30 μm depth. The diameter and height of the bump type spot was 800 μm diameter and 50 μm height. These spots were observed on the surface even in the dumbbells stage. These spots don't occur in neither the surface treatment nor EBW process. The location of these spots was within 15 mm from a joint point of the equator. To understand "Are these suspicious spots become heating source?", the thermo-sensor attached on the suspicious spots at vertical test. The heating of these suspicious spots of both cavities were not detected by T-map at ~ 39.9 MV/m in the pass-band measurement. The observed suspicious spots in 2nd series cavity are not reason of limitation of cavity performance at this moment.

The gradient of 2nd series cavity was achieved 27 MV/m (MHI-05) and 28 MV/m (MHI-06).

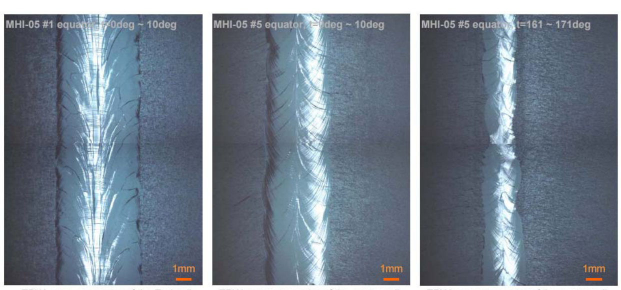


Figure 4: Typical EBW seam of MHI-05 "as built" at equators.

Inspection of 3rd series cavity (MHI-07 ~ 09)

A parameter of EBW of equators was studied for 3rd series cavity to obtain the smooth and uniform EBW seam [3]. The 3rd series cavity was fabricated at 2009. As a result, the EBW seams of 3rd series cavity were improved (see Figure 5) by the new EBW parameter. The qualities of EBW seam for three cavities were similar.

The gradient of 3rd series cavity was achieved 34 MV/m (MHI-07), 38 MV/m (MHI-08) and 27 MV/m (MHI-09) [4],[5],[6]. The cavity performance was limited by field emission.

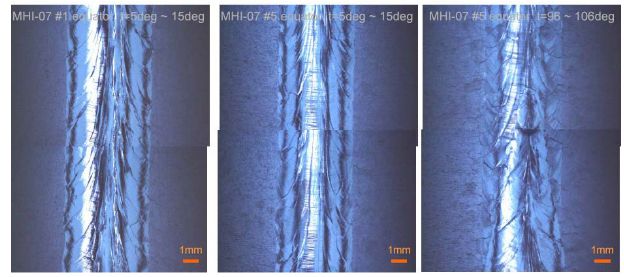


Figure 5: Typical EBW seam of MHI-07 "as built" at equators.

Inspection of 4th series cavities (MHI-10 ~ 11)

4th series cavity was fabricated at Nov 2009. These cavities are used for S0 program of ILC to compare the surface treatment method at each lab. The initial surface treatment and vertical test will be done until Sep 2010 at KEK-STF.

SUMMARY

Correction of defects size and quench field is under collecting by combination of optical inspection with high-resolution camera and T-mapping. The defects existed around equator in 1st series cavity though the surface was grind by CBP at initial treatment. The uniform EBW seam is also important to obtain better yield of accelerating gradient.

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